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SOME PHYSICAL AND FRICTIONAL PROPERTIES OF SWEET DETAR NUT AND SEED

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ABSTRACT

The physical and frictional properties of sweet detar nut and seed were determined at their respective moisture content of 7.34% and 6.11%. Measurement yielded an average length of 35.871 mm, width of 31.422 mm and thickness of 16.261 mm for the nut, while seed average length, width and thickness were 21.523, 19.700 and 9.082 mm respectively. The seed and shell respectively constituted about 25.58 and 74.42% of nut by mass. The average roundness and sphericity of nut ranged from 81.06 to 97.18%, and 68.12 to 76.78% and the corresponding values for seed ranged from 90.6 to 99.8%, and 55.8 to 81.7% respectively. The average unit mass, volume, bulk density, true density and porosity of the nut and seed were 7.39 and 2.48 g, 7.86 and 1.68 cm^3, 0.5361 and 0.8218 g/cm^3, 1.0288 and 1.307 g/cm^3 and 47.76 and 36.31% respectively. The coefficient of static friction of nut on galvanized iron sheet, glass and plywood were 0.4314, 0.3544 and 0.5072, while the corresponding values for seed were 0.3592, 0.1696 and 0.2365 respectively.

KEYWORDS: Sweet detar, physical properties, frictional property, nut and seed.

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INTRODUCTION

Sweet detar (*Detarium Senegalense*) is a leguminous tree crop that belongs to the family caesalpiniaceae. Its natural distribution extends through arid sub-Saharan Africa from Senegal to Sudan. Its fruit contains a nut and its pulp is eaten raw or processed into juices, local beer and baby food. The nut contains a seed (Figure 1) that has a protein content of 12% which is rich in rare amino acid lysine and tryptophan (N R C, 2008). In Nigeria and many other West African countries the seeds are cooked and eaten as snacks, processed to extract oil, use as soup thickening ingredient, use for animal feed, and transformed into hip collars. The utilization of the seeds into various products makes them suitable for large scale handling and processing. Suitable

equipment and machines necessary for handling and processing them can only be developed if their physical properties are known.

The size and shape of nut and seed are important for the design of cleaning, sorting and grading equipment. Bulk density, true density and porosity are important factors in designing of storage structures. The angle of repose is also useful in the design of hopper, bin and silo. Static coefficient of friction is used to determine the angle at which chutes must be positioned in order to achieve material free flow through the chute.

(a) (b)

Figure 1: Nuts (a) and seeds (b) of sweet detar fruit.

Physical properties of several agricultural products have been investigated for similar purpose. Aviara *et al*., (2000), Owolarafe *et al*., (2007), Dash *et al*., (2008), Fo'hat *et al*., (2011), Ch'ng *et al*., (2013) and Davis and Mohammed, (2013) determined the size of shea nut and kernel, palm fruit, simarouba fruit and kernel, Acorn, ginkgo nuts and kernels and bitter kola nuts and shell respectively, by measuring their principal axial dimensions. Aviara *et al*., (2000), Jannatizadeh *et al*., (2008), Naderiboldaji *et al*., (2008) and Aviara *et al*., (2014), correlated the values of these dimensions for sheanuts and kernel, Iranian apricot fruit, sweet cherry fruit and date pulps and kernels respectively. Aviara *et al*., (2000), Altuntas and Erkol, (2010), Ch'ng *et al*.,(2013) and Aviara *et al*., (2014) developed the frequency distribution curves for the axial dimensions and mass of sheanut, shelled and kernel walnuts, ginkgo nuts and kernels, and date fruits palm respectively. Other properties that have been investigated by these researchers include roundness, sphericity, true density, bulk density, porosity, angle of repose and static coefficients of friction.

The objective of this study was to determine the physical properties of sweet detar nut and seed, namely principal axial dimensions, roundness, sphericity, 1000 mass nut and seed, true density, bulk density, porosity and static coefficient of friction at equillibrium moisture content.

MATERIALS AND METHODS

Sample preparation and moisture content determination

For this study, about 100 kg of dried sweet detar fruit was purchased from Gamboru market, Maiduguri, Borno State, Nigeria, in the year 2014. The entire fruits were soaked in water for about 24 hours and then gently squeezed in water pool in order to wash away pulp and obtain nuts. The resulting nuts were sundried for a week, cleaned and sampled for experiment using a multi-slot riffle box divider. Intact seeds were obtained by manually cracking nuts. The resulting nuts and seeds were stored in sealed polyethylene bags.

ASAE Standards S352.2 (ASAE, 2003) for moisture content determination of seeds was used to determine the moisture content of nut and seed. This method involved oven drying of sample at 130^{o}C for 72 hours, with weight loss monitored to give an idea of the time at which the weight began to remain constant. The moisture content for nut and seed were found to be 7.34% and 6.11% respectively. Tests were carried out on the nut and seed at their respective moisture content.

Determination of size and shape

The sizes of nut and seed were determined by measuring their three principal axial dimensions namely length, width and thickness. Sample of 100 units each for nut and seed were randomly selected and their length, width and thickness were measured using Vernier calipper reading to 0.01 mm accuracy. The mass of each of the 100 nut and seed selected was measured on an electronic digital weighing balance reading to 0.01 g.

Geometric mead diameter (GMD) was calculated using the relationship

$$GMD = (L \times W \times Th)^{1/3} \tag{1}$$

where L is length (mm), W is width (mm) and Th is thickness (mm) of sample.

The equivalent diameter (de) for nut and seed was calculated by determining the volume of equivalent sphere (Ve) of sample using water displacement method. The equivalent diameter was calculated using the equation suggested by Jayas and Cenkowski (2006):

$$de = \left(\frac{6Ve}{\pi}\right) \tag{2}$$

Frequency distribution of dimension and mass for nut and seed was determined and the correlation between length and width, thickness and mass of nut and seed was established.

The roundness and sphericity of nut and seed were determined using the shadowgraph method (Mohsenin, 1986; Aviara *et al*., 2014). The method of shadowgraph involved tracing the projected areas of 30 nuts and seeds on a graph sheet and counting the squires of the projected and small circumscribing areas and measuring the diameters of inscribing and circumscribing circles (Figure 2). Values for roundness and sphericity of nut and seed were calculated using the following expressions respectively:

$$R = \left(\frac{Ap}{Ac}\right) \quad (3)$$

$$S = \left(\frac{di}{dc}\right) \quad (4)$$

where R is the roundness (%), Ap is projected area (mm^2), Ac is smallest circumscribing area (mm^2), S is spericity and di and dc are inscribing and circumscribing diameter respectively.

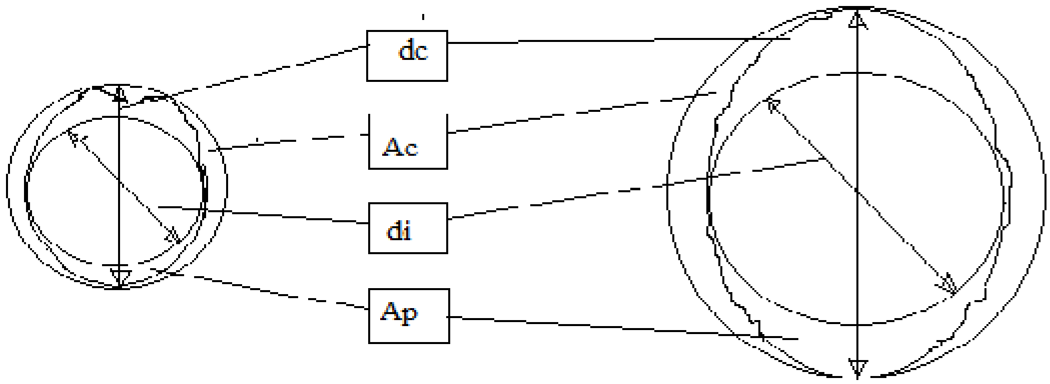

Figure 2: Typical shadowgraphs of sweet detar nut and seed, dc-diameter of circumscribed circle, Ac-area of circumscribed circle, di-diameter of inscribed circle, Ap-projected area

Determination of gravimetric properties

The 1000 unit mass was determined by respectively weighing randomly selected 100 nuts and seeds on an electronic weighing balance reading to 0.01 g and multiplying the resulting weight by 10 and this was replicated 30 times. True density was determined using water displacement method (Mohsenin, 1986). Samples were coated with very thin layer of resin to prevent absorption of water during experiment. A coated sample was weigh, submarged and held

suspended in a container placed on a weighing balance and containing enough water to submarge sample. Increased weight recorded by the balance was recorded as weight of displaced water and true density was calculated using equation (5):

$$\rho_t = \rho_w \frac{Mp}{Mw} \tag{5}$$

where ρ_t true density (g/cm^3), ρ_w is density of water (g/cm^3), Mp sample mass (g) and Mw mass of water (g). Bulk density was detarmined using the AOAC, (1980) method. This involved filling of a 1500 ml cylinder with sample from a height of 150 mm and weighing its content. Porosity was calculated using the following relationship (Mohsenin, 1986):

$$\varepsilon = [1 - \frac{\rho b}{\rho t}\ ] \times 100 \tag{6}$$

Determination of frictional property

The static coefficient of friction of nut and seed was determined on three structural surfaces namely galvanized steel sheet, glass and plywood respectively. The inclined plane method was used (Dutta *et al*., 1988; Mohsenin, 1986). This involved placing of a topless and bottomless box on an adjustable tilting surface which was formed with a structural surface mensioned earlier. The box was filled with sample and lifted to 2 mm above the structural surface to establish only sample and structural surface contact. The entire set up was gradually raised with a screw device until the box just started to slide down. The tilt angle was read from a graduated scale and the tangent of this angle was taken as the static coefficient of friction.

Statistical analysis

Experimental data obtained were subjected to descriptive statistical analysis. Coefficient of correlation analysis was done to investigate the level of significance between ratios of sizes and mass. ANOVA was used to investigate the effect of structural surface on static coefficient of friction. All statistical analysis were done using statistix version 9 statistical software.

RESULTS AND DISCUSSION

Size and shape of nut and seed

The results obtained from the measurements of nut and seed physical properties are presented in Table 1. Figure 3 (a and b) shows the frequency distribution curves for length, width, thickness and goemetric mean diameter of nut and seed respectively. The trend shown by each curve tends toward a normal distribution.

Table 1: Some physical, gravitational and frictional properties of sweet detar nut and seed

Property	No. of Observation	Nut			Seed		
		Mean	Maximum	Minimum	Mean	Maximum	Minimum
Length (mm)	100	35.871(3.5617)*	42.650	28.740	21.523(1.7738)	26.438	17.860
Width (mm)	100	31.422(2.7813)	36.861	24.300	19.700(1.7963)	23.007	15.040
Thickness (mm)	100	16.261 (1.60205)	19.700	11.000	9.082 (1.0090)	11.995	6.071
Geometric mean diameter (mm)	100	26.326 (2.0968)	30.642	20.373	15.648 (1.2018)	18.752	12.761
Equivalent mean diameter (mm)	100	24.540 (1.898)	27.130	21.233	14.669(1.1211)	16.842	12.810
Mass (g)	100	7.39 (1.638)	11.08	3.92	2.48 (0.493)	4.05	1.47
Roundness (%)	30	89.88 (5.137)	97.18	81.063	97.38 (2.959)	99.80	90.60
Spherisity (%)	30	72.41 (3.010)	76.78	68.12	70.98 (6.93)	81.70	55.80
Volume (cm^3)	30	7.860(1.7419)	10.450	5.010	1.680 (0.0386)	2.500	1.100
1000 mass (g)	30	8024.82 (461.28)	8914.0	6908.0	2758.71 (387.42)	2782.62	2714.0
Bulk density (g/cm^3)	30	0.536 (0.0105)	0.550	0.522	0.822 (0.0190)	0.846	0.785
True density (g/cm^3)	30	1.029 (0.0144)	1.054	1.003	1.307 (0.0075)	1.450	1.221
Porosity (%)	30	47.76 (1.212)	49.65	46.38	36.31 (1.461)	38.66	34.07

*: Numbers in parentheses are standard deviation

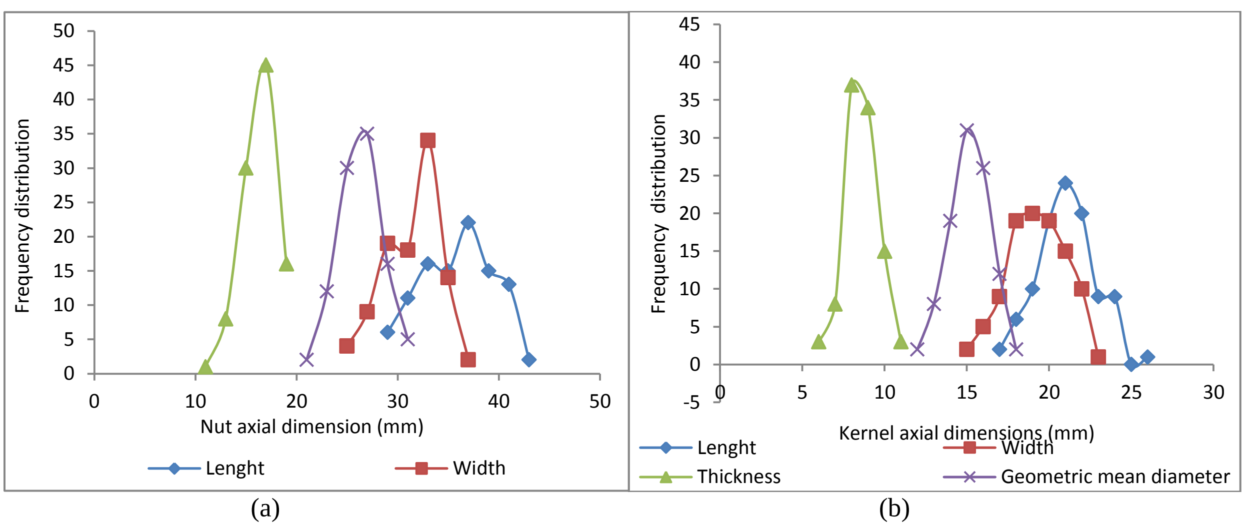

Figure 3: Frequency distribution curves of the dimensions of sweet detar nut (a) and seed (b)

About 33% of nuts were small size (L_n < 35 mm), 37% were medium size (33 mm < L_n < 39 mm) and 30% were large size (L_n> 39 mm). While about 63% of seeds were medium size (19.5 mm < L_s < 22.5 mm), 18% were small size (L_s < 19.5 mm) and 19% were large size (L_s > 22.5 mm). The result of percentage size distribution indicated that seed size did not correlates with with nut size.

It was established that the following general expression could be used to describe the relationships among the dimensions and mass of nut and seed respectively.

$$L_n = 1.1419W_n = 2.2223Th_n = 5.008M_n \quad (7)$$
$$L_s = 1.0947W_s = 2.394Th_s = 8.934M_s \quad (8)$$

Table 2 presents the values of coefficient of correlation between length and width, thickness and mass. L_n/W_n, L_n/M_n, L_s/W_s and L_s/M_s ratios are strongly correlated and highly significant. This indicates that width and mass of sample are closely related to their length, while their thickness does not indicate much association. The seed was found to constitute about 25.58% of nut by mass while the shell was about 74.42%.

Values of roundness and sphericity of nut and seed were respectively presented in Table 1. It was found from the study that the value of roundness of seed is higher than nut, while nut has higher value of sphericity than seed (Table 1). The roundness values of sweet detar nut and seed were found to be higher than the corresponding values of sheanut and kernel reported by Aviara et al., (2000). The sphericity values of sweet detar nut and seed were however lower than those of sheanut and kernel respectively. Table 1 shows that sweet detar nut and seed have roundness and sphericity values above 89% and 70% respectively. Therefore, the nut and seed can be treated as round and sphere in analysis requiring an approximation of their shape.

Table 2. Coefficient of correlation and probability level

Ratio	Correlation Coefficient	P-value
L_n/W_n	0.8711	0.0000
L_n/Th_n	0.3285	0.0008
L_s/W_s	0.8645	0.0000
L_s/Th_s	0.2885	0.0036
L_n/M_n	0.849	0.0000
L_s/M_s	0.7883	0.0000

Gravimetric properties of nut and seed

The result for unit mass and 1000 mass for nut and seed are presented in Table 1. From the table, it can be seen that nut had the higher mass value. The frequency distribution curves for mass of nut and seed are presented in Figure 4. The trend shown by nut curve tends toward a bimodal distribution while seed tends toward a normal distribution. The values of bulk density, true

density and porosity of sweet detar nut and seed are also presented in Table 1. Nut had lower bulk density value than seed. This indicates that nut would require more space for storage per unit mass than seed. The true density of nut and seed showed that seed had the higher value and from their respective values it can be concluded that nut and seed would sink in water. The values of porosity of nut and seed shown indicate that nut had more void space than seed.

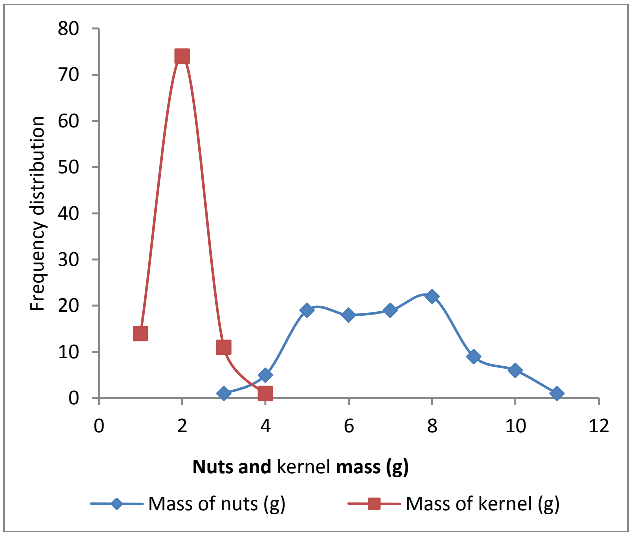

Figure 4: Frequency distribution curves of the mass of sweet detar nut and seed

Frictional properties of nut and seed

The results of the coefficient of static friction of sweet detar nut and seed determined on structural surfaces are presented in Table 3. It was found that the structural surfaces had significant effect on the coefficient of static friction of nut and seed (p-value of 0.000). The coefficient of static friction for nut was highest on plywood surface and lowest on glass surface, while galvanized iron sheet and glass surfaces provided the highest and lowest frictional resistance for seed respectively.

Table 3. Coefficient of Static Friction of Sweet detar nut and seed on three different surfaces

Coefficient of Static friction	No. of Observation	Nut			Seed		
		Mean	Maximum	Minimum	Mean	Maximum	Minimum
Glass	10	0.3544 (0.0354)[a]	0.404	0.3057	0.1696 (0.0185)[d]	0.1853	0.1495
Plywood	10	0.5072 (0.0327)[b]	0.543	0.4663	0.2365 (0.0249)[e]	0.2679	0.2035
Iron	10	0.4314 (0.012)[c]	0.4452	0.4245	0.3592 (0.0299)[f]	0.4040	0.3443

Mean values with same letter within a column are insignificant

CONCLUSION

1. The length, width and thickness for sweet detar nut varied from 28.74 to 42.65 mm, 24.3 to 36.86 mm and 11.00 to 19.70 mm respectively, while the corresponding dimensions for seeds varied from 17.86 to 26.438 mm, 15.04 to 23.007 mm and 6.071 to 11.995 mm for length, width and thickness respectively.

2. The roundness and sphericity values for nuts were 89.88% and 72.41% respectively, while the corresponding values for seeds were 97.38% and 70.98% respectively.

3. The mean unit mass and volume for nut and seed were 7.39 g and 7.86 cm^3, and 2.48 g and 1.68 cm^3 respectively.

4. The bulk density, true density and porosity for nut were 0.536 g/cm^3, 1.029 g/cm^3 and 47.755% respectively, while for seed the values were 0.822 g/cm^3, 1.307 g/cm^3 and 36.31% respectively.

5. The coefficient of static friction for nuts were higher than the corresponding values for seed.

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